The Met.Office

FORECASTING SYSTEMS TECHNICAL NOTE NO.10

A TRIAL OF ENHANCEMENTS TO THE TROPICAL CYCLONE BOGUSSING SCHEME

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OCTOBER 1998

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1. INTRODUCTION

In 1994 a new scheme for the initialisation (bogussing) of tropical cyclones (TCs) was introduced into the Met. Office atmospheric models (Heming, 1994(a), Heming et. al., 1995). The scheme is used for every active tropical cyclone for every run of the model and in 1996 was fully automated. Results indicated that use of the new scheme reduced TC forecast track errors by 30% when compared to results with the previous technique employed. Figure 1 illustrates the structure of the bogus data generated by the scheme.

Early in 1998, the global model resolution was increased in the horizontal from 216x288 to 324x432 grid points and in the vertical from 19 to 30 levels. Early trials indicated that the increased resolution produced deeper centres on tropical cyclones both in the analysis and forecast. The new horizontal grid spacing of 0.83°x0.55° should enable the model to resolve a finer structure near the centre of the tropical cyclone. It should also be possible to improve the resolution of detail further by restructuring the bogus data generated near to the centre. To this end, it was decided to carry out a trial of a restructured bogus scheme with the aim of increasing the depth of the inner core of tropical cyclones in the model without expanding their overall size and without having any detrimental effect on track forecasts.

2. TRIAL OF RESTRUCTURED BOGUS SCHEME

The restructured bogus scheme replaces the inner ring of 4 bogus points of radius 2° with two rings of radii 1.25° and 2.5°, each containing 4 bogus points. The remaining bogus rings remained unaltered as did all other principles of the scheme. Hence, the restructured bogus scheme can have up to five rings of bogus data (a total of 32 points), whereas the current scheme can have up to four (a total of 28 points). The restructured scheme can be seen diagrammatically in Figure 2.

A trial of the restructured scheme was undertaken from June to August 1998 in the form of four separate experiments. See Table 1 for details of the experiment periods and tropical cyclones involved. In each experiment, bogus data were created by the current scheme and fed into 'control' (CNTL) forecasts. Bogus data were also created by the restructured scheme and fed into 'trial' (TRIAL) forecasts. In this way, it was possible to be certain that the only differences seen were due to the different bogus data. During each experiment a continuous assimilation cycle was maintained so that the effects of bogus data in the current run are fed through to the next run.

3. VERIFICATION OF RESULTS

Tables 2-5 show verification results for each individual experiment and Table 6 shows combined statistics for all experiments.

3.1 Intensity Verification

The UKMO TC verification scheme (Heming, 1994(b)) uses the local maximum of 850mb relative vorticity to track the centres of TCs. Similarly, in these experiments, the maximum value of 850mb relative vorticity was used to measure the relative intensities of the TRIAL and CNTL forecasts.

As was expected, every analysis produced using the restructured bogus scheme produced a more intense centre than those using the operational bogus scheme. On average, TRIAL analyses were 23% stronger than CNTL analyses (as measured by 850mb relative vorticity). This is a result of the bogus wind values being assimilated. The inner ring bogus wind values at 1.25° in the restructured scheme were significantly higher than the inner ring bogus wind values at 2° in the operational scheme. Checks were made during the trial to ensure that the new inner ring bogus values being used were not excessive relative to the actual strength of the TC. This was not found to be a problem.

The intensity increase seen in analyses dropped off markedly during the forecast to mean values of 12.8% at T+24 and 4.5% at T+120. However, the TRIAL intensity was greater than the CNTL intensity in every forecast case. On average for all TRIAL forecasts, TC intensity was increased by 10% relative to CNTL.

The global model is not able to represent the inner core strength of TCs at its current resolution. Hence, any increase in strength can be seen as a positive impact. However, the global model *can* represent the overall size of a TC with some accuracy. Hence, any increase in inner core strength should not be accompanied by an overall expansion of size of TCs in the model. During the trial, this was monitored and it was found that whilst the TRIAL analyses and forecasts had deeper centres, the outer closed isobar and outer values of 850mb relative vorticity remained almost unchanged. This can be seen in Figures 3 and 4. Figure 3 shows the CNTL analysis for Hurricane Blas at 12UTC 24 June 1998. The overlaid shaded area indicates where the CNTL and TRIAL mean sea-level pressure values differed by more than 0.5mb. Similarly, Figure 4 shows the CNTL analysis with shaded overlay of where the 850mb relative vorticity difference between CNTL and TRIAL is more than 5×10^{-6} s^{-1}. Both of these indicate that the area of increased strength in the TRIAL analysis is restricted to an area close to the core of the TC. This is what would be expected given that bogus values on the 4°, 6° and 8° rings were identical in the CNTL and TRIAL runs. This would have constrained any inclination the model may have had towards expanding the overall size of the TC in the TRIAL runs due to the greater bogus wind strengths near the centre.

3.2 Track Verification

The prime reason for undertaking these experiments was to attempt to deepen TC centres in the model. However, the effects on track verification need to be assessed, since if track forecasts were worsened by the change it would not be implemented. Accurate track prediction is considered to be more important that intensity prediction.

The verification statistics show a large (37%) reduction in analysis error when using the TRIAL construction. This is to be expected due to the tighter definition of the TC centre produced by the inner ring of bogus data at radius 1.25°. However, forecast errors showed much smaller differences. In experiments 3 and 4 there were some cases of an increase in TRIAL forecast errors. However, when viewed overall, track forecasts showed a modest 1.5% improvement under the restructured bogus scheme. There were more than twice as many individual cases where the TRIAL analysis or forecast error was smaller than the CNTL error than vice versa.

4. SUMMARY and CONCLUSIONS

The northern hemisphere TC season made a slow start in 1998, which meant these experiments were not conducted during an ideal active trial period. However, it was possible to carry out experiments on 8 different tropical cyclones from the north-west Pacific, north-east Pacific and Atlantic basins during a six week period.

The following can be concluded from the results:-

- The restructured bogus scheme produces deeper centres on TCs in both the analysis and forecasts. The current resolution of the global model cannot resolve the true inner core strength of TCs. Hence, any increase in strength seen in the model is considered to be an improvement.

- The deeper centres seen on TCs do not produce an overall expansion in the size of TCs in the model.

- The restructured bogus scheme reduces analysis positional errors and in the trial cases produced a small reduction in forecast error. The relatively small number of cases combined with the modest forecast error reduction mean no conclusion can be drawn as to whether track forecasts will consistently improve once the restructured bogus scheme is implemented. However, from these results it is reasonable to state that no worsening of track forecasts will result from this change to the bogussing scheme.

On the basis of these results it was decided to implement the restructured bogus scheme operationally. This was done on 22nd September 1998.

5. REFERENCES

Heming, J.T. (1994(a)). A Trial of a New Technique for the Bogussing of Tropical Cyclones *Central Forecasting Technical Note No.22*. National Meteorological Library, Bracknell, UK.

Heming, J.T. (1994(b)). Verification of Tropical Cyclone Forecast Tracks at the UK Met. Office. *nwp Gazette,* **1**, No.2:3-8.

Heming, J.T., Radford, A.M. & Chan, J.C.L. (1995). A New Scheme for the Initialisation of Tropical Cyclones in the UK Meteorological Office Global Model. *Met. Apps,* **2**:171-184.

Experiment number	Dates	Tropical cyclones
1	23-29 June	Hurricane Blas (NEP)
2	7-10 July	Tropical Storm Nichole and Tropical Depression 01W (NWP)
3	17-20 July	Tropical Storm Celia (NEP)
4	27 July-3 August	Hurricanes Darby and Estelle (NEP), Tropical Storms Alex (NAT) and Otto (NWP)

Basin name abbreviations:-
NEP : North-East Pacific
NWP : North-West Pacific
NAT : North Atlantic

Table 1
Details of Experiments

	T+0	T+24	T+48	T+72	T+96	T+120
No. of cases	14	12	10	7	5	3
Intensity increase (%)	27.6	15.3	16.5	12.3	9.2	4.7
TRIAL error (km)	23	90	180	316	540	865
CNTL error (km)	33	95	188	339	575	890
Error reduction (%)	30.3	5.3	4.3	6.8	6.1	2.8

Comparative results indicate TRIAL relative to CNTL

Mean results:
Forecast intensity increase: 13.4%
Forecast track error decrease: 5.2%
Analyses and forecasts: TRIAL error smaller: 37
CNTL error smaller: 8
Errors equal: 6

Table 2
Verification of Experiment No.1

	T+0	T+24	T+48	T+72	T+96	T+120
No. of cases	13	11	7	4	0	0
Intensity increase (%)	27.2	10.1	10.2	10.0	-	-
TRIAL error (km)	52	183	283	424	-	-
CNTL error (km)	80	196	307	443	-	-
Error reduction (%)	35.0	6.6	7.8	4.3	-	-

Comparative results indicate TRIAL relative to CNTL

Mean results:
Forecast intensity increase: 10.1%
Forecast track error decrease: 6.8%
Analyses and forecasts: TRIAL error smaller: 21
CNTL error smaller: 7
Errors equal: 7

Table 3
Verification of Experiment No.2

	T+0	T+24	T+48	T+72	T+96	T+120
No. of cases	6	4	2	-	-	-
Intensity increase (%)	24.1	9.1	9.5	-	-	-
TRIAL error (km)	34	181	196	-	-	-
CNTL error (km)	64	179	191	-	-	-
Error reduction (%)	46.9	-1.1	-2.6	-	-	-

Comparative results indicate TRIAL relative to CNTL

Mean results:
Forecast intensity increase: 9.2%
Forecast track error decrease: -1.6% (i.e. error *increase*)
Analyses and forecasts: TRIAL error smaller: 7
CNTL error smaller: 3
Errors equal: 2

Table 4
Verification of Experiment No.3

	T+0	T+24	T+48	T+72	T+96	T+120
No. of cases	35	31	25	21	16	11
Intensity increase (%)	23.2	11.4	9.3	6.4	3.6	3.4
TRIAL error (km)	28	124	224	267	340	476
CNTL error (km)	45	124	219	271	342	474
Error reduction (%)	37.8	0.0	-2.3	1.5	0.6	-0.4

Comparative results indicate TRIAL relative to CNTL

Mean results:
Forecast intensity increase: 7.9%
Forecast track error decrease: -0.2% (i.e. error *increase*)
Analyses and forecasts: TRIAL error smaller: 82
CNTL error smaller: 47
Errors equal: 10

Table 5
Verification of Experiment No.4

	T+0	T+24	T+48	T+72	T+96	T+120
No. of cases	68	58	44	32	21	14
Intensity increase (%)	24.8	12.8	11.6	8.7	4.5	4.5
TRIAL error (km)	32	132	222	297	388	559
CNTL error (km)	51	135	225	307	398	563
Error reduction (%)	37.3	2.2	1.3	3.3	2.5	0.7

Comparative results indicate TRIAL relative to CNTL

Mean results:
Forecast intensity increase: 10.0%
Forecast track error decrease: 1.5%
Analyses and forecasts: TRIAL error smaller: 147
CNTL error smaller: 65
Errors equal: 25

Table 6
Verification of All Experiments Combined

SUMMARY OF FIGURES

Figure 1 The Tropical Cyclone Bogussing Scheme (25 October 1994 to 22 September 1998)

Figure 2 The Tropical Cyclone Bogussing Scheme (22 September 1998 onwards)

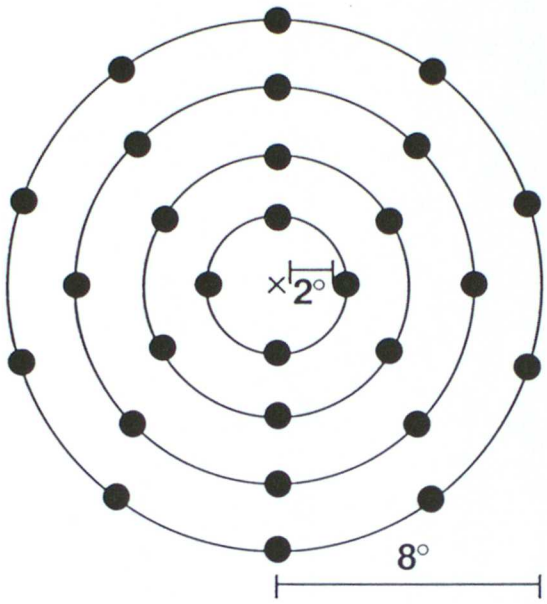
Figure 3 DT 12UTC 24.06.1998, Hurricane Blas.
Contours: CNTL mean sea-level pressure (2mb interval).
Shading: CNTL-TRIAL differences in mean-sea-level pressure where differences are greater than 0.5mb.

Figure 4 DT 12UTC 24.06.1998, Hurricane Blas.
Contours: CNTL mean sea-level pressure (2mb interval).
Shading: CNTL-TRIAL differences in 850mb relative vorticity where differences are greater than 5×10^{-6} s^{-1} (negative values only)

Figure 1

THE UK METEOROLOGICAL OFFICE TROPICAL CYCLONE BOGUSSING SCHEME

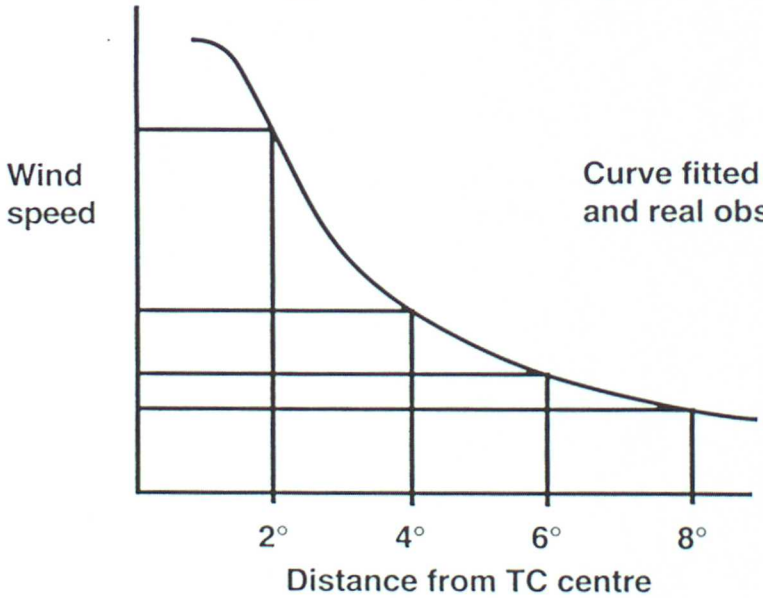
Horizontal distribution of bogus points



Past 6-hours movement vector

6° ring used if maximum sustained wind >30 knots
8° ring used if maximum sustained wind >40 knots

Tangential wind speeds at bogus points



Curve fitted to advisory information and real observations

Asymmetry
Past 6-hours movement vector added to all tangential winds

Low-level convergence
Inflow of 12° at the surface only

Upper wind strengths
850 hPa: 100% of surface wind

700 hPa: 95% of surface wind

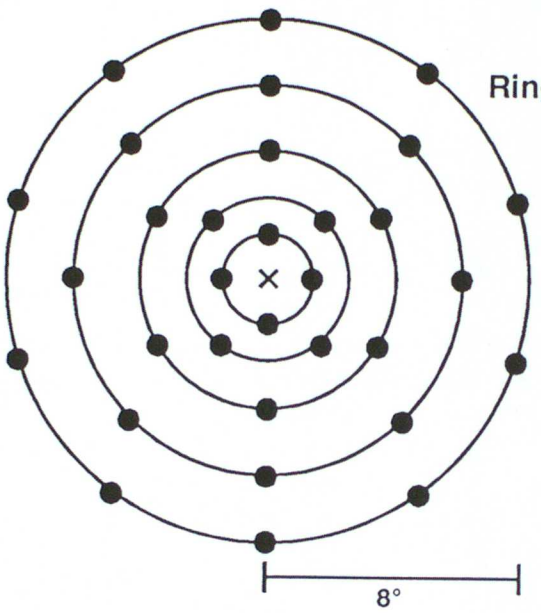
500 hPa: 85% of surface wind

Figure 2

The UK Meteorological Office Tropical cyclone bogussing scheme

(September 1998 configuration)

Horizontal distribution of bogus points

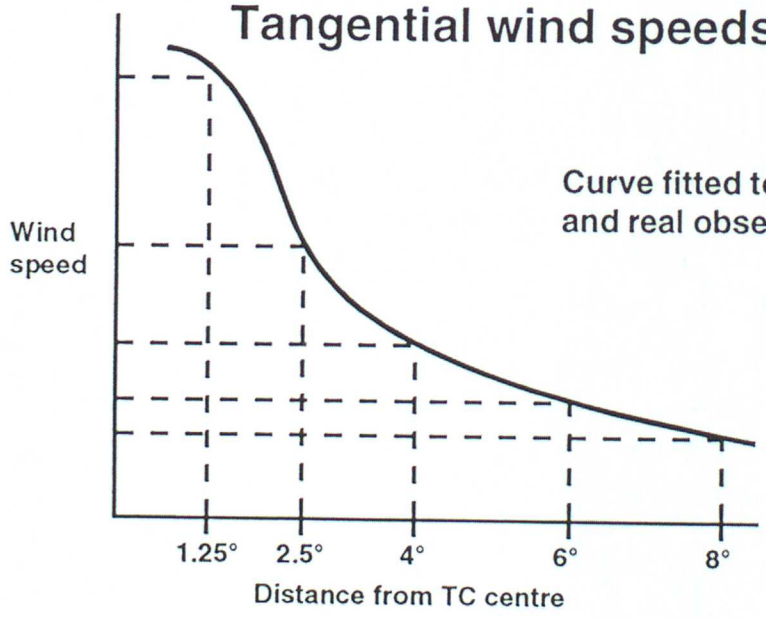


Ring radii: 1.25°, 2.5°, 4°, 6°, 8°

Past 6-hours movement vector

6° ring used if maximum sustained wind >30 knots
8° ring used if maximum sustained wind >40 knots

Tangential wind speeds at bogus points



Curve fitted to advisory information and real observations

Asymmetry
Past 6-hours movement vector added to all tangential winds

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Inflow of 12° at the surface only

Upper wind strengths
850 hPa: 100% of surface wind

700 hPa: 95% of surface wind

500 hPa: 85% of surface wind

Figure 3

MSLP: CNTL analysis and CNTL-5RING difference shading (>0.5mb)

VALID AT 12Z ON 24/ 6/1998 DAY 175 DATA TIME 12Z ON 24/ 6/1998 DAY 175

Hurricane Blas

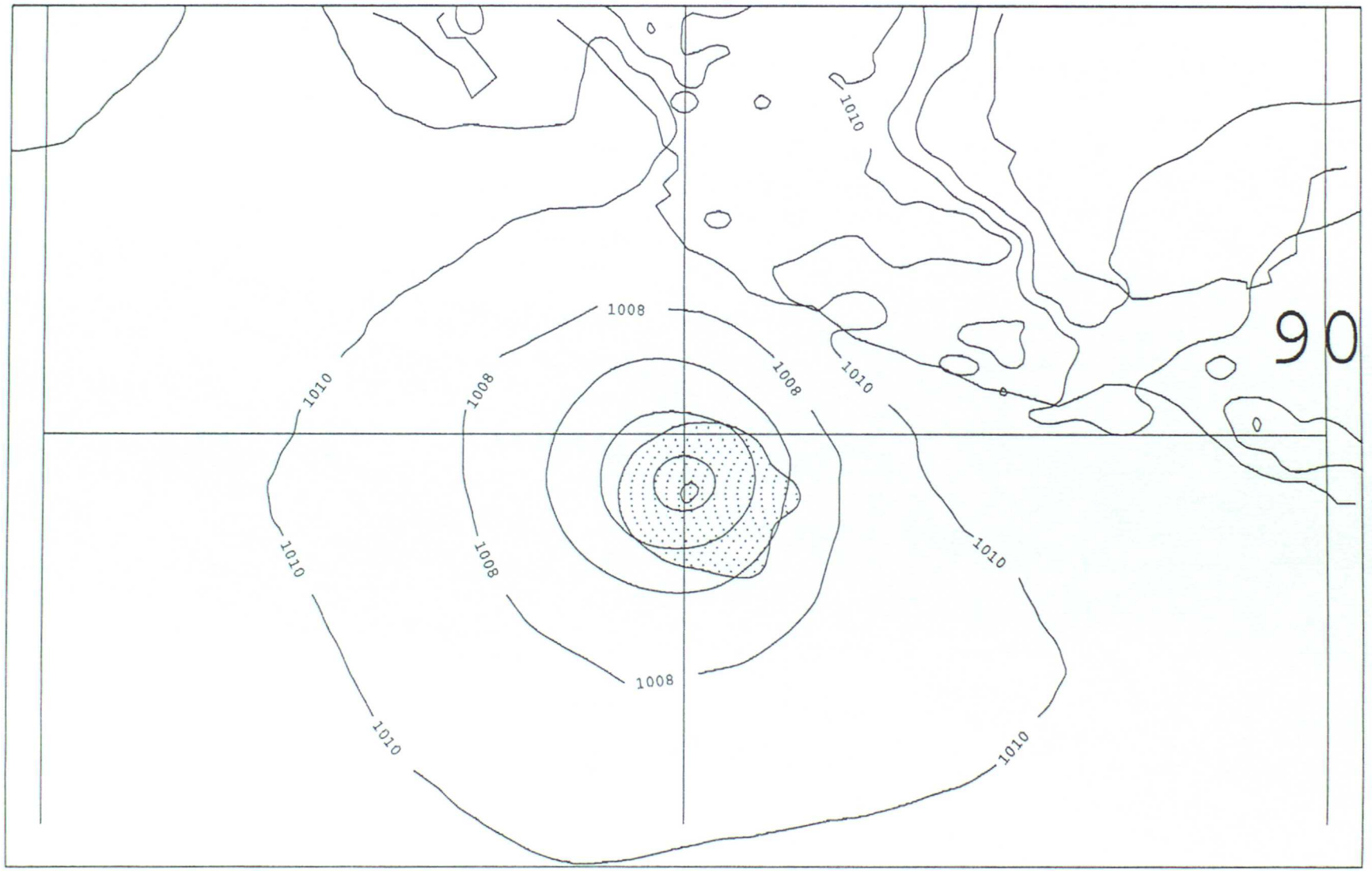

Figure 4

CNTL MSLP analysis & CNTL-5RING 850mb RV difference shading (<-5x10**-6 /sec)

VALID AT 12Z ON 24/ 6/1998 DAY 175 DATA TIME 12Z ON 24/ 6/1998 DAY 175

Hurricane Blas